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The present research was conducted to determine transfer of practice from a formation simulator to actual aircraft flight for the wing aircraft component of the formation flying task. Evidence in support of positive transfer was obtained by comparing students trained in the formation simulator with students who were essentially untrained and with students trained in the aircraft. This design provided data for a direct comparison of five simulator sorties with two aircraft sorties in an effort to quickly establish a training cost/transfer comparison. The results indicate that the simulator has at least the training effectiveness of two aircraft sorties. (Author/JB)

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TRANSFER OF TRAINING WITH FORMATION FLIGHT TRAINER

By

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Flying Training Division

Approved for publication.

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The present research was conducted to determine transfer of practice from a formation simulator to aircraft formation flying. Evidence in support of positive transfer was obtained by comparing students trained in the formation simulator with students who were essentially untrained and with students trained in the aircraft. This design provided data for a direct comparison with five simulator sorties with two aircraft sorties in an effort to quickly establish a training cost/transfer comparison. The results indicate that the simulator has at least the training effectiveness of two aircraft sorties.

PREFACE

This study was conducted under Project 1123, USAF Flying Training Development; Task 112302, Instructional Innovations in USAF Flying Training.

TABLE OF CONTENTS

		Page
I.	Introduction	5
II.	Method – Study I	5
	Subjects	5
	Equipment	6
	Procedures	7
	Instructor Pilots	7
	Performance Assessment	7
III.	Results – Study I	9
IV.	Method – Study II	10
	Subjects	10
	Instructor Pilots	10
	Performance Assessment	10
V.	Results – Study II	11
VI.	Discussion – Study I and Study II	12
References		13

LIST OF TABLES

Table		Page
1	Number and Type of Flying Sorties by Treatment Group	7
2	Analysis of Variance: Aircraft Performance Scores – Study I	9
3	Differences Among Means of Performance Scores – Study I	9
4	Analysis of Variance, Weighted Scores – Study I	10
5	Differences Between Group Means Weighted Scores – Study I	10
6	Analysis of Variance, Performance Scores – Study II	11
7	Differences Among Means of Performance Scores – Study II	11
8	Analysis of Variance, Weighted Scores – Study II	11
9	Differences between Group Means Weighted Scores – Study II	12

TRANSER OF TRAINING WITH FORMATION FLIGHT TRAINER

I. INTRODUCTION

Any time two or more aircraft move from one place to another, the most expeditious and efficient way to do so is in groups, provided the group is ordered, disciplined and performs predictably. A competently led formation is the best method because it allows application of the best leade-ship and provides a way to move a number of aircraft through limited airspace without overcrowding that airspace or control facilities. Additionally, it provides a redundant navigation and communications capability for all aircraft in the flight. Flying in close proximity to another aircraft during maneuvering flight is one of the most demanding requirements of military aviation. As a formation member, the pilot must be disciplined and aggressive with quick and precise reactions. Formation training is unique in that it has always been conducted exclusively in the aircraft. This is a stressful situation which most assuredly does not provide the conditions most conducive to learning. Flight simulators offer an alternative training environment which this study was designed to investigate.

The effectiveness of flight simulators has repeatedly been demonstrated in instrument training (Valverde, 1968; Kelly, 1970). The advent of practical visual flight simulators, and their demonstrated effectiveness by the commercial airlines (Gibson, 1969) has greatly expanded the role of simulation in flying training. Prompted by this expansion, the Air Force developed a simple visual flight simulator that allows a student to practice formation flying prior to instruction in an aircraft (Wood, Hagin, O'Connor, & Myers, 1972). A previous study, in which an attempt was made to provide limited information practice in the F100/151 Fixed Gunnery Trainers, suggested that such a trainer would be effective (Pfeiffer, 1963). Pfeiffer's study demonstrated improvement in ability to maintain formation position in the simulator in spite of equipment limitations that prevented the student from flying closer to the lead aircraft than 2,000 feet. However, the effect of this training on subsequent formation flying in an aircraft was not studied.

In the present research, the investigator sought to demonstrate the transfer of simulator practice to actual aircraft flight for the wing aircraft component of the formation flying task. Two studies were conducted in the T-38 phase of United States Air Force Undergraduate Pilot Training (UPT) using a prototype Formation Flight Trainer (FFT). These studies were designed to provide a direct answer to an applied question: "Can the FFT provide enough training to justify purchasing them in quantity for inclusion in UPT?" Based on projected unit cost of producing FFTs, pilot production rates and estimated training cost, it was determined that cost-effectiveness would be achieved if the FFT could reduce formation practice in an aircraft by at least two hours.

The second study is essentially a replication of the first study, brought about by a change in instructional policy of the USAF Air Training Command (ATC). The materials, procedures, etc., were the same for both studies. The principal difference in the two studies was the prior experience in formation flying of the students.

In study I, the students were essentially naive to formation flying. They had flown approximately three demonstration sorties in the T-37 (their first training airplane). These sorties were composed primarily of demonstration by the instructor pilot. In the second study, the students had flown approximately seven sorties in T-37 formation. At the end of these seven sorties, the student was required by the training syllabus to be able to fly formation without the instructor pilot accompanying him in the airplane.

II. METHOD – STUDY I

Subjects

Seventy students were selected for this study from UPT classes 73-08 and 73-09 at Williams AFB, Arizona. The classes were divided into three study groups for the T-38 formation phase of UPT. At this stage of training, the students had completed approximately 82.5 hours of flying training in the T-37 aircraft and 30 hours in the T-38. There was no reason to believe that these classes were different from any other class of UPT students and, therefore, they were considered a sample from the population of UPT trainees. The sample was restricted to United States citizens without flying experience prior to entering UPT.

ATC planning is to develop UPT for the middle 68% of the trainee distribution and to individually manage the 16% low ability and the 16% high ability students (Mission Analysis Study Group, 1972). To assure that the samples for this study would provide data compatible with this philosophy, the students in each flight of the classes involved were ranked on their flying ability, as defined by the average of all checkride scores, at the end of the T-37 phase of training. Two students from the low 16% and two students from the high 16% were randomly assigned to each of three groups for each class. An additional eight students randomly selected from the middle 68% of each class completed the groups. Comparison of the mean scores of the groups' final T-37 scores indicated that they were not significantly different ($p > .05$) in flying ability. In class 73-09, two students were eliminated from training on their contact checkride subsequent to being selected and prior to entering the formation phase. Therefore, a total of 70 subjects participated in the study.

Equipment

The FFT is a simulation system which provides a realistic two-aircraft formation flight situation (Figure 1). The trainer provides the student with a wide angle projected television picture of a T-38 lead aircraft that is continuously variable in range, relative bearing and relative altitude. The picture of the lead aircraft can be commanded by an instructor pilot (IP) to perform standard maneuvers while the student attempts to maintain position in formation by control actions from his own simulated T-38 aircraft cockpit. A detailed description of the FFT can be found elsewhere (Wood et al., 1972).

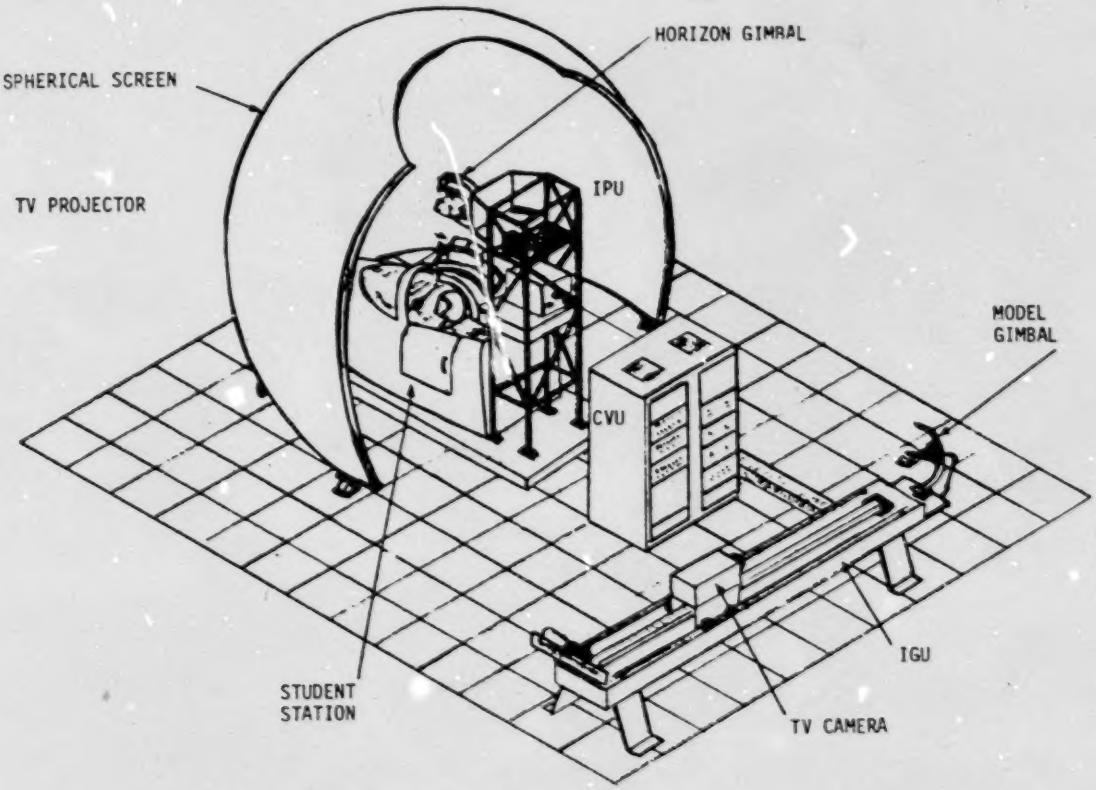

Figure 1. **Formation flight trainer.**

Procedures

The three comparison groups of the complete random design are depicted in Table 1. Treatments were randomly assigned to the groups as follows: Group A was the FFT-trained or experimental group; Group B was a limited training group; and Group C was an aircraft or UPT-syllabus trained group. Previous experience with the FFT indicated that five sorties was a reasonable and useful number for an average UPT student and, therefore, it was decided for this study to use five 50-minute FFT sorties, in a block, prior to aircraft practice. Sorties length of 50 minutes was selected to conform to current UPT practice and block presentation was selected because of its demonstrated effectiveness in instrument training in flight simulators (Wilcoxson, Davy, & Webster, 1954; Reid, Hagin, & Coats, 1970; Woodruff, Smith & Morris, 1974). Each of the five FFT sorties was instructed by a different IP in an effort to control for IP differences in experience or ability. The IPs were allowed to use any sequence of maneuvers and instructional technique they desired.

Table 1. **Number and Type of Flying Sorties by Treatment Group**

	Sorties			
Groups	FFT	Aircraft Orientation F51-01	Aircraft Training	Aircraft Study Data Ride
A. FFT	5	1	0	1
B. Limited Training	0	1	0	1
C. UPT Syllabus	0	1	2	1

Subsequent to flying the FFT sorties, the A group flew a sortie in the T-38. The purpose of this sortie was to allow the student to put what he had learned in the simulated flight environment into the airplane context. Either a sixth trainer IP, or the trainer IP who had instructed the first FFT sortie, flew this aircraft sortie with the student. All maneuvers were demonstrated and differences between the T-38 and FFT were emphasized. The day following the aircraft orientation ride, the student flew a T-38 checkride and his ability to fly the airplane through nine basic maneuvers was evaluated.

Group B received only an aircraft orientation ride. All maneuvers were demonstrated and explained during the orientation ride. Thus, on the following day when a student was asked to attempt a maneuver on a data checkride, he at least had been shown the desired performance.

Each group C student flew the first three aircraft sorties as if they were not part of a study. The first sortie was essentially the same as the one flown by groups A and B, except it was flown with the student's normally assigned IPs. The day following the third aircraft sortie, the student flew the data checkride

Instructor Pilots

Eight IPs from the 97th Flying Training Squadron were instructors in FFT and the aircraft orientation rides for groups A and B. The IPs had approximately a week to fly the FFT and discuss its capabilities with other IPs and study personnel prior to the start of the study. They were selected from different flights according to their willingness to take on an additional duty and their supervisors' approval of their reduced availability for regular flying duty. There is no evidence to suggest that these IPs were not representative of all IPs at Williams AFB, Arizona.

Performance Assessment

An assumption was made that the most reliable assessment of student ability would be provided by the experienced and highly standardized squadron "check section" pilots using a grading system similar to and compatible with the existing grading system. Check section pilots are trained observers who regularly fly approximately five checkrides a week. Ten check pilots were used with all but one IP flying at least five data checkrides. One check pilot flew as few as four checkrides and one flew thirteen checkrides. Attempts to control the number of students from each group that each check pilot flew with were unsuccessful.

The grading scale used was an expansion of the existing UPT grade scale. The existing scale measures a student's ability to fly a maneuver as follows:

Unable to Accomplish (U):	The student lacked sufficient knowledge, skill, or ability to perform the element, operation, maneuver, or task without assistance.
Fair (F):	The student performed the element, operation, maneuver, or task but made some false starts, repetitions, or minor errors of omission or commission.
Good (G):	The student performed the element, operation, maneuver, or task correctly, with little hesitation.
Excellent (E):	The student performed the element, operation, maneuver, or task correctly, quickly, and efficiently.

Since the students were being evaluated at a very early stage of training, it was anticipated that they would all score in the U or F categories. In an effort to increase sensitivity, an expansion to a 12-point scale was devised which allowed an IP to score performance in the upper half, lower half, or middle of each of the existing scale units.

The 12-point scale was defined as follows:

U	1.	Instructor had to assume control almost immediately to avoid collision.
	2.	Instructor eventually had to assume control as performance deteriorated.
	3.	Instructor never assumed control; however, performance was still unsatisfactory.
F	4.	Performance very rough; however, instructor found that verbal assistance corrected problem.
	5.	Performance rough – minimal verbal assistance would correct problem.
	6.	Performance rough; however, no verbal assistance necessary – practice should improve performance.
G	7.	Performance somewhat smoother than an F student; however, becomes rough after short time.
	8.	Performance somewhat smooth but continuously passes through desired position.
	9.	Performance smooth – deviations from desired position last several seconds.
E	10.	Performance very smooth – after deviations aircraft returned to position quickly.
	11.	Performance very smooth – deviations are small and aggressively corrected.
	12.	No deviations noted. Perfect position maintained.

A precisely defined data checkride profile was developed to insure that all students were evaluated in the same way. The profile consisted of the following nine maneuvers: straight and level, shallow bank turns (15° – 20°), medium bank turns (30° – 40°), steep bank turns (60° – 90°), route, crossunder, echelon turns (45° bank), turning rejoin and straight ahead rejoin. The order of the nine basic formation maneuvers was precisely defined to prevent students from having diferent amounts of practice prior to evaluation. When the profile called for a turning maneuver, one was flown in each direction prior to check IP assigning a grade. The initial turn could be in either direction. In this way, the check IP was able to keep the aircraft in the assigned flying area with minimum interference to the profile. When operational restrictions prohibited the flying of the next maneuver as defined by the profile, the IP took control of the aircraft until the profile could be executed. Check IPs were asked not to instruct on any maneuver until after checkride completion. The lead aircraft was always flown by an IP rather than the student to insure that lead was as stable as possible for all students flying wing. The data checkride was not part of the normal training program and was inserted at the appropriate time according to which group the student was assigned. Upon completion of the data checkride, the remainder of the student formation training was performed as prescribed by the training syllabus.

The grade for each student's data checkride was derived by multiplying each maneuver grade by a weight extracted from the operational ATC checkride. These weights account for the varying difficulty and importance of the maneuvers to the entire operational task. The nine maneuver grades were then summed and transformed to standard scores with a $\sigma = 10$ and $X = 50$ (Guilford, 1965). The equation used was:

$$\left(\frac{10}{\sigma_o}\right)\overline{X}_o - \left[\left(\frac{10}{\sigma_o}\right) M_o - 50\right] = T \text{ where:}$$

M_o = Mean grade assigned by a particular check pilot.

σ_o = Standard deviation of grades assigned by a particular check pilot.

X_o = Observed grade for one student by a particular check pilot.

This standard score transformation was performed to partially compensate for the subjective nature of the observations combined with the effect of ten check pilots making an unequal number of observations.

III. RESULTS – STUDY I

The data checkride grades for the three groups were analyzed by a one-way analysis of variance (Table 2). The differences between the three groups were statistically significant $F(2,66) = 7.42$, $p < .05$. Calculation of an Omega Square indicates that the treatment effect accounted for 15.7% of the variance.

Table 2. **Analysis of Variance: Aircraft Performance Scores – Study I**

Source	DF	MS	F
Between Groups	2	598.26	7.42*
Within Groups	66	80.66	
Total	68		

*$p < .05$.

Subsequent to the analysis of variance, an "a posteriori test" (Tukey's HSD), was performed to ascertain significance for between group comparisons (Kirk, 1968). As indicated in Table 3, both the FFT-trained (Group A) and the UPT syllabus-trained (Group C) groups scored higher than the limited training group (Group B). The difference in both comparisons was significant at the .05 level. The mean for the UPT syllabus-trained group was higher than the mean for the FFT-trained group but the difference was not found to be significant at the .05 level.

Table 3. **Differences Among Means of Performance Scores – Study I**

Groups		$\overline{X}_B$	$\overline{X}_A$	X_C
X_B (Limited Training)	= 44.02	--	6.66*	10.04*
X_A (FFT)	= 50.68	--	--	3.38
X_C (UPT Syllabus)	= 54.06	--	--	--

N = 69.

*$p < .05$.

Since the nine maneuvers have different degrees of importance to the flying task, weights were assigned to the maneuvers and the one-way analyses of variance was repeated using the weighted data. The weights were extracted from the current UPT two-ship checkride as defined by ATC. This analysis revealed results comparable to the previous analysis $F(2,66) = 7.42$, $p < .05$ (Table 4). The between group comparisons are presented in Table 5.

Table 4. **Analysis of Variance, Weighted Scores – Study I**

Source	DF	MS	F
Between Groups	2	599.26	7.42*
Within Groups	66	80.66	
Total	68		

N = 69.
*$p < .05$.

Table 5. **Differences Between Group Means Weighted Scores – Study I**
(Formation Flight Trainer Application to UPT)

Groups	Differences Between Group Means		
	A	B	C
A. FFT	--	--	--
B. Limited Training	6.66*	--	--
C. UPT Syllabus (3 Sorties)	3.38	10.04*	--

N = 69.
*$p < .05$.

IV. METHOD – STUDY II

The description of method for study II is the same as study I with the execptions described subsequently.

Subjects

Forty-eight students were selected from UPT class 74-06 at Williams AFB, Arizona. The class was divided into three study groups for the T-38 formation phase of UPT. At this stage of training, the students had completed approximately 90 hours of flying training, eight of which were formation in the T-37 aircraft and 30 hours in the T-38. The sample was selected and assigned to treatments according to the procedures used in study I.

Instructor Pilots

Eight IPs from the 97th Flying Training Squadron were instructors in the FFT and in the aircraft orientation rides for the A group. None of the IPs from study I participated in Study II. They were selected from different flights according to the procedures established in study I.

Performance Assessment

In an effort to gain better control of the evaluation procedure, the use of pilots from the squadron check section was abandoned. The work load of the check section necessitates the use of a relatively large number of observers. Even though check section is highly standardized, it was decided that better control could be obtained by having a smaller number of observers trained to observe factors related to this study.

Equally as important, this procedure had less impact on the squadron's training mission. The number o check pilots was reduced to four and line instructors were used. After the start of the study two of thes pilots had to be replaced. Therefore, the students were evaluated by six IPs. The students' data checkrid scores were derived according to the procedures developed in study I.

V. RESULTS – STUDY II

The data checkride scores for the three groups were analyzed with a one-way analysis of variance. Th differences between the three groups were statistically significant F (2,39) = 5.33, $p < .05$ (Table 6) Calculation of an Omega Square indicates that the treatment effect accounted for 17.5% of the variance.

Table 6. **Analysis of Variance, Performance Scores – Study II**

Source	DF	MS	F
Between Groups	2	449.51	5.33*
Within Groups	39	84.23	
Total	41		

*$p < .05$.

Subsequent to the analysis of variance, and "a posteriori test" (Tukey's HSD) was performed t ascertain significance for the between group comparisons (Kirk, 1968). As indicated by Table 7, both th FFT-trained (Group A) and the UPT syllabus-trained (Group C) groups scored higher than the limite training group (Group B). The difference in both comparisons was significant at the .05 level. The mean fo the FFT-trained group was higher than the mean for the UPT syllabus-trained group but the difference wa not found to be significant at the .05 level.

Table 7. **Differences Among Means of Performance Scores – Study II**

Groups		B	C	A
B. (Limited Training)	= 43.49	--	9.92*	11.82*
C. (UPT Syllabus Trained)	= 53.41	--	--	1.90
A. (FFT)	= 55.31	--	--	--

N = 42.
*$p < .05$.

The analysis of the weighted scores, as in study I, revealed results comparable to the unweighted I (2,21) = 5.33, p

Table 8. **Analysis of Variance, Weighted Scores – Study II**

Source	DF	MS	F
Between Groups	2	449.52	5.33*
Within Groups	39	84.23	
Total	41		

N = .43.
*$p < .05$.

Table 9. **Differences Between Group Means Weighted Scores – Study II**

Groups		Differences Between Group Means A	B	C
A. (FFT)	= 55.31	--	--	--
B. (Limited Training)	= 43.49	11.82*	--	--
C. (UPT Syllabus Trained)	= 53.41	1.90	9.92*	--

N = 43.
*$p < .05$.

VI. DISCUSSION – STUDY I AND STUDY II

The present research was conducted to determine transfer of practice in a formation flight simulator to formation flying in the aircraft. Evidence in support of positive transfer was obtained in these two studies by comparing the mean performance of students in the FFT-trained groups with the mean performance of students in the limited training groups. Students trained in the FFT scored significantly better than the essentially untrained students, indicating that simulator training resulted in improved performance in the T-38 aircraft. Likewise, comparing the means of the UPT syllabus-trained groups with the limited training groups means confirms the obvious, that practice on a task improves performance on that task. However, differences between FFT-trained groups and the UPT syllabus-trained groups fail to attain statistical significance. These comparisons lead to the conclusion that both training methods are effective at this early stage of the student's skill acquisition. Since student performance does not indicate that one training method is obviously superior, then other factors, such as cost of training, should be included in selection of a training program.

A post hoc analysis of group equivalence was performed using scores from the contact phase of training. The contact checkride was the last activity participated in prior to starting the formation training phase and should provide information about differences in flying ability at the start of the study. An analysis of variance failed to show any statistically significant differences in these contact scores. Although these data are indicators of flying skill, they could not be used in the analysis as a pretest because the scores come from different flying tasks. These data, however, do lend support to the conclusion that the observed differences in the studies were treatment effects.

Study II was conducted for two reasons. The first was to replicate study I in order to increase confidence in the results. The second was to determine the effect of a change in the UPT syllabus. Results of the second study did not reveal any change from study I, which permits some interesting speculation. The limited training group for study II was expected to score higher on the data checkride than the limited training group for study I, since they had received twice as many formation trianing flights in the T-37. But scores obtained in study II do not indicate a higher skill entry level for T-37 formation-trained students. However, it is possible that the overall level of proficiency at the conclusion of T-38 formation is higher with the additional training, but these investigations did not attempt to answer this question.

A primary consideration in understanding the contribution to training of any simulator is the way in which the device is used. The purpose of these studies was to examine the contribution of the simulator *per se*. In order to avoid biasing the outcome of these studies with transfer not directly attributable to the simulator, a conservative approach was taken in the development of instructional strategies. Such things as assuring that each student was instructed by a different IP each day and allowing the IP to teach according to his own plan are examples of this approach. It is suggested that the development of effective instructional strategies, the definition of the amount of useful simulator practice and determination of how formation simulator can best complement aircraft instruction will result in a substantial increase in the FFT's training effectiveness.

Results from these studies, especially in light of their repeatability, provide conclusive evidence that the formation simulator is an effective training device.

Future research with this prototype simulator should define more effective instructional uses and scheduling sequences. The resultant training program will undoubtedly provide more efficiently trained pilots.

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